UCRL-JC-117389 Extended Abstract

PRODUCTION OF HOLLOW MICROSPHERES FOR INERTIAL CONFINEMENT FUSION EXPERIMENTS

Robert C. Cook
Lawrence Livermore National Laboratory
Livermore, CA

Symposium W2: Hollow and Solid Spheres and Microspheres

Paper: **W2-3.2** **Date:**
Time: **Location:**

We make hollow plastic microspheres half a millimeter in diameter with extremely smooth surfaces—surface roughness is about 0.004% of the microsphere's diameter. (For comparison, ball bearings this size typically are about six times rougher—their surface roughness is about 0.025% of their diameter.) We make and use a few hundred of these microspheres, or capsules, each year in connection with our research in laser-driven nuclear fusion. This paper focuses on the preparation of these capsules, and gives background information on the nature of laser-driven fusion.

Researchers worldwide are working to "harness" nuclear fusion—the process by which the stars get their energy—so as to produce electrical energy. In fusion, the nuclei of relatively light elements are forced together; the result is the production of several other particles, with slightly less total mass, accompanied by the release of energy. (Einstein's equation $E = mc^2$ tells how much energy corresponds to the loss of a mass m in the reaction.) Produced in sufficient quantities, fusion energy could be captured as heat, which could be used to run steam turbine generators.

The most likely candidate fusion fuels are deuterium (a heavy form of hydrogen that makes up a small percentage of all water everywhere on Earth) and tritium (a heavier, radioactive form of hydrogen, which can be made using lithium, also found in water). Electrical energy generated from such common materials could meet the Earth's energy needs for thousands of years.

Researchers at the Lawrence Livermore National Laboratory are pursuing laser-driven "inertial confinement" fusion (ICF), in which gaseous deuterium, contained in a small, spherical plastic shell, is compressed using high-powered laser beams. The laser beams heat the surface of the shell; as the outside of the shell (called the ablator) burns off, the reaction force accelerates the rest of the shell inward, compressing and heating the deuterium inside. If high enough densities and temperatures can be produced in the center of the capsule, fusion reactions will begin, and the rest of the fuel will be consumed in further reactions. (The fuel's inward motion is all that keeps it together long enough for all this to occur; this leads to the name "inertial confinement" for the process.)

The typical current ICF capsule is about 0.5 millimeters in diameter, and consists of three thin layers. The inner layer (called the pusher, because its inner surface actually compresses the fuel) is a plastic shell 2 to 3 micrometers thick. Next comes a layer of a polymer, polyvinyl alcohol (PVA), also 2 to 3 micrometers thick, used to greatly slow the diffusion of high-pressure deuterium out of the capsule. The outer layer (the ablator) is about 50 micrometers thick, and consists of a extensively crosslinked hydrocarbon plastic.

We produce the pusher shells in a “drop tower”: droplets of polymer solution are dropped down a heated tower fifteen to twenty feet high. The solvent evaporates as the droplets fall, leaving a hollow polymer shell. The PVA layer is added in a second drop-tower operation. The ablator layer is laid down by a plasma-assisted polymerization coating technique similar to those used in the semiconductor industry.

The result is capsules with the very smooth, uniform ablator layers essential for successful ICF experiments. Surface variations, measured using a precision technique called atomic force microscopy, are generally less than 0.02 micrometers, peak to valley. For comparison, ball bearings typically have six times greater roughness, about 0.12 micrometers. (With respect to the capsule diameter, the capsule roughness is 20 parts in 500,000, or 0.004%.)

The capsule surface must be smooth to help overcome one of ICF’s most difficult problems—the capsule’s strong tendency to implode asymmetrically. This tendency results from the so-called Rayleigh-Taylor instability, which makes any perturbations in the ablator surface get bigger as the capsule is compressed. The perturbations can become big enough to reach the inner surface of the capsule, mixing relatively cool pusher material with the hot compressed fuel and spoiling the compression.

To study the effects of surface finish on implosion characteristics, we use a precision-focused excimer laser to controllably roughen the capsule surface.

Current plans are to construct a new ICF laser facility called the National Ignition Facility that will be powerful enough to generate, in appropriate targets, at least as much fusion energy as the energy in the laser beams used to compress the capsule. These target capsules will be at least 2 millimeters in diameter; they will contain liquid or solid hydrogenic fuels at very low temperatures, and their inner walls may be composed of low-density foam to help to hold the liquid fuel.

Work performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.